Art. XV.—*On the Age of the Alkali Rocks of Port Cygnet and the D'Entrecasteaux Channel in S.E. Tasmania.*

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Introduction.

The remarkable series of alkali rocks at Port Cygnet, Woodbridge, and other localities on the D'Entrecasteaux Channel, present many features of mineralogical and petrographic interest. They have been made known principally by the researches of Mr. W. H. Twelvetrees, F.G.S., Government Geologist of Tasmania, in a series of papers in which he has described their mineralogical and petrographic characters as shown in the field and under the microscope. He has also discussed the difficult and vexed question of their age. Other geologists and petrologists who have contributed to our knowledge of these rocks include the late Mr. Petterd, the late Professor Rosenbusch, and Dr. F. P. Paul. During a visit to South-East Tasmania in January, 1916, I examined this district. Mr. Twelvetrees was good enough to show me the chief outcrops, and to discuss the problems with me in the field, while Dr. W. N. Benson, of Sydney University, was with us in the earlier part of our stay at Port Cygnet.

This brief paper results from the discovery at Little Oyster Cove, Kettering, of evidence bearing on the vexed question of the age of the alkali series in this part of Tasmania.

Previous Literature.

(1) The earliest reference to the alkali rocks of this area, apart from their approximate distribution as shown on the Geological map in Johnston's Geology of Tasmania, 1888, appears to be a paper by Twelvetrees and Petterd, entitled "On Havyne Trachyte and allied rocks in the districts of Port Cygnet and Oyster Cove. (Proc. Roy. Soc., Tas., 1898-9.)

(2) In the handbook for the Aust. Assoc. for Advancement of Science, Hobart, 1902, Mr. Twelvetrees gave a sketch of the Geology of Tasmania, in which he referred to the elaeolite syenites,

phonolites and trachytes at Port Cygnet (pp. 24, 26 and 27), and tentatively referred them to the top of the Permo-Carboniferous series.

(3) Mr. Twelvetrees, in a paper, entitled "A Geological Excursion to Port Cygnet," in connection with the Australasian Association for the Advancement of Science, 1902, published by Roy. Soc., Tasmania, 1902, in the course of a report on the excursion described the modes of occurrence and petrological characters of the chief rock types then known, including in his report petrographic determinations by Professor Rosenbusch.

(4) Mr. Twelvetrees contributed a "Note on Jacupirangite in Tasmania," to the Roy. Soc., Tasmania, 1902, in which he described the occurrence of this rock among the alkali intrusions of Port Cygnet.

(5) Mr. Twelvetrees, in a paper, entitled "On the Nomenclature and Classification of Igneous Rocks in Tasmania," published by the Aust. Assoc. for Adv. of Science, New Zealand, 1904, pp. 264-305, discussed the position of the alkali series in a review of the classification of the igneous rocks of the State.

(6) Dr. F. P. Paul published a paper, entitled "Foyaitisch-Theralitische Gesteine aus Tasmania," in Min. Petr. Mitt., Vienna, 1906, pp. 269-318, in which he recorded detailed chemical and petrological work among the alkali series.

(7) Mr. Twelvetrees made a "Report on Gold at Port Cygnet and Wheatley's Bay, Huon River," published in Report of Secy. of Mines, Tasmania, 1907, in which he associates the gold occurence with quartz veins developed in the metamorphosed sediments of Lower Permo-Carboniferous age at the contact with the alkali intrusive rocks.

(8) Mr. Twelvetrees, in his "Outlines of the Geology of Tasmania," published in the Report of the Secretary for Mines for 1908-1909, pp. 133, 141 and 142, regarded as unsettled the precise age of the elaeolite and alkali syenites, with various alkaline porphyries at Port Cygnet and along D'Entrecasteaux Channel, but placed them at the top of the Permo-Carboniferous series in Tasmania, above the horizons of the Southport sandstones and shales, and the Mt. Cygnet and Adventure Bay sandstones and shales, of which the latter is correlated with the Newcastle series of New South Wales. On pp. 141, 142 it is stated that the alkaline rocks which form a S.W., N.E. belt running from the Huon River through Port Cygnet to Woodbridge and Kettering, are referred provision-

ally to the close of this period (Permo-Carboniferous). It is definitely known that they are intrusive into the Lower Marine sandstones and mudstones, and they appear to be cut through by the diabase which is considered to date from the close of the Mesozoic. The belt comprises the following rock varieties:—

Alkali Syenites.—Quartz augite syenite, Aegirine augite syenite, Alkali syenite porphyry.

Elaeolite Syenites.—Pyroxene foyaite, Mica foyaite, Jacupirangite, Amphibole foyaite porphyry, Sölvsbergite porphyry, Mica sölvsbergite, Tinguaite porphyry, Monchiquite nephelinite.

Essexite.—Essexite.

Auriferous quartz and pyrites have been developed near the line of contact of these igneous rocks with the Permo-Carboniferous sediments, and a good deal of alluvial gold has been recovered from the creeks and flats.

(9) Dr. H. I. Jensen, in Proc. Linn. Soc., N.S.W., 1908, pp. 557-558, referring to the rocks of the Port Cygnet group, remarked on their general close resemblance to Australian alkaline rocks, and stated that they were considered without very much evidence to be of Lower Mesozoic age. They are known to be later than the Permo-Carboniferous, and to antedate the Pliocene, but direct evidence to fix their age more closely appears to be wanting.

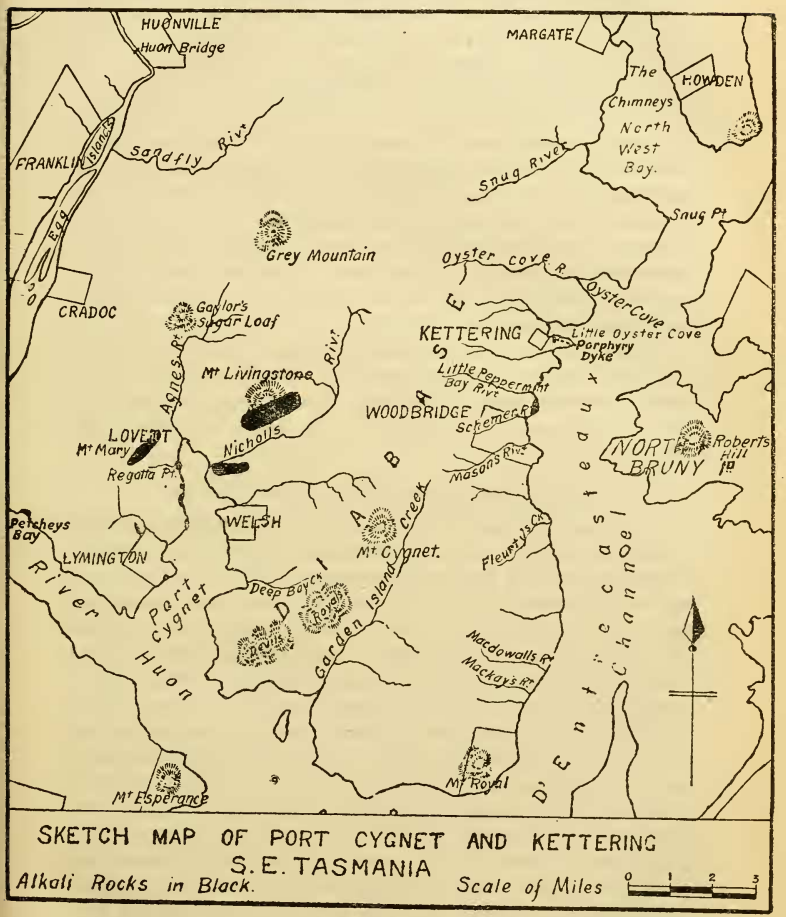
(10) Professor David and the writer wrote a chapter on the igneous rocks in the Geology of the Commonwealth in the Federal Handbook on Australia for the British Association meeting of 1914. On p. 309, under the heading, Jurassic (?) (possibly Triassic), they refer to the foyaitic rocks of the Port Cygnet series. These rocks are considered to be perhaps of Lower Mesozoic age. They are all strongly intrusive into the Permo-Carboniferous series, but their relations to the Jurassic sedimentary rocks and to the diabase have not yet been clearly demonstrated.

Distribution of the Alkali Rocks.

Two groups of outcrops of alkali rocks occur in this district,[1] one in the S.W. of the area on the shores of the Huon River and of Port Cygnet, the other in the N.E. part of the area, on the shores of Peppermint Bay and Little Oyster Cove on D'Entrecasteaux Channel. The exposures of alkali rocks in the first group in the S.W. of the area include the following:—An outcrop in Petchey's Bay on the Huon River, dykes of porphyry at Lymington, a quarter

1 See locality map.

of a mile south of Shag Point on Port Cygnet. N.W. of this is the akerite or quartz augite syenite outcrop, 1½ miles up Forester's



Rivulet on the back road to Mt. Mary. North of this is the plexus of alkali rocks composing Mt. Mary. East of this on the shores of Port Cygnet are the main outcrops of the much-differentiated alkali-rich rocks of Regatta Point, and various other localities

along the coast southwards for 1½ miles. Stretching inland from the opposite or N.E. shores of Port Cygnet another outcrop of alkali rocks occurs along the Peppermint Bay Road. One mile N.E. of the town of Lovett are the alkali rocks of Livingstone Hill. The second group of alkali rocks occurring in the N.E. of the area consists of the alkali porphyry of Woodbridge towards the northern extremity of Peppermint Bay. Two outcrops occur here, intruding the Permo-Carboniferous sediments. Permo-Carboniferous glacial beds outcrop in Little Peppermint Bay. Further north, on the south side of Little Oyster Cove, diabase, Permo-Caboniferous sediments and alkali porphyry are all represented.

Between these two groups of outcrops in the S.W. and N.E. of the area a gap of 8 or 9 miles occurs, consisting mostly of hilly country, in which up to the present the only rocks known are diabase and Permo-Carboniferous sediments.

I visited all the localities mentioned above under Mr. Twelvetrees' guidance, with the exception of the outcrop in Petchey's Bay, which I have not seen. I am indebted to one of my students, Mr E. O. Cudmore, for specimens of the alkali rock from this locality.

Field Occurrence of the Alkali Rocks.

In all the localities examined the alkali rocks present the characters of intrusive rocks. The petrographic descriptions by Mr. Twelvetrees and by Professor Rosenbusch indicate that so far as textural characters go some of the porphyries, with fine-grained ground-mass, show fluidal and other characters, which occur in lava flows, but since these textures are also represented in dyke rocks and the field relations are generally clear, their intrusive character is practically placed beyond question. Some of the coarser-grained varieties near Regatta Point and the akerite mass on the back road from Lymington to Mt. Mary are described as syenites of various kinds, but they occur as relatively small intrusions, intimately associated with the smaller dykes, and are best regarded as hypabyssal in origin, and described as larger dyke-like masses. In every case except the one presently to be described these rocks have penetrated the Lower Marine series of the Permo-Carboniferous sediments. Junction specimens were obtained from south of Regatta Point, and from Mt. Mary and at the latter place especially the Permo-Carboniferous rocks near the contact are considerably altered. They have been converted into indurated and silicified rocks, more or less pyritized, and have been penetrated

by small quartz veins, which, as Mr. Twelvetrees has described, have shed a fair quantity of gold, since recovered in alluvial workings near by.

The Porphyry Dyke Cutting the Diabase at Kettering.

While the age of the alkali series is thus proved to be post Lower Permo-Carboniferous, its relations to the only other rock of the district, the diabase, have hitherto remained obscure. A ridge of diabase runs down the eastern side of the peninsula formed between the D'Entrecasteaux Channel, Port Cygnet and the Huon River, and on the western part of the peninsula Permo-Carboniferous rocks outcrop at the surface. Although Mr. Twelvetrees and other geologists have made several traverses across this ridge separating the S.W. and the N.E. occurrences of alkali rocks, no members of the alkali series have yet been found in any part of this intervening ridge. Impressed by this negative observation Mr. Twelvetrees has explained it on the supposition that the alkali rocks are older than the diabase.

In the latter part of our visit Mr. Twelvetrees and I worked northwards from the alkali outcrops at Woodbridge on the north edge of Peppermint Bay, past the Permo-Carboniferous glacial deposits of Little Peppermint Bay to Little Oyster Cove at Kettering.

On the south side of Little Oyster Cove, going east for about 150 yards beyond the jetty, we found the diabase came down to the shore. At this point a low outcrop, a few feet in height, occurs, and an abrupt change from diabase to alkali porphyry was observed. The porphyry extends for 15 to 20 feet, and then just as abruptly diabase comes in again, and remains nearly to the east extremity of the bay, which is occupied by Permo-Carboniferous sediments, while on rounding the point to the south diabase comes in again.

There is no doubt in my mind that the occurrence of Porphyry with parallel walls and in abrupt contact with the diabase represents an intrusion of porphyry into the diabase. The only alternative explanation of the relations of the two rocks that occurs to me is that of a large mass of porphyry detached by and included in the diabase. I reject the latter explanation, and adhere to the view that the porphyry is part of a dyke for two reasons. The first is that although the exposure is limited, one can see that the walls in contact with the diabase are parallel as one would expect to find in a dyke. The second reason is that at the contact with

the diabase the porphyry for about half-an-inch in width is quite different in texture from the central part of the mass. The small porphyritic crystals are set in an exceedingly fine-grained paste or ground-mass, much finer in texture than the normal ground-mass, away from the contact. This feature I regard as a selvage to the dyke produced by the rapid chilling of the intrusive mass against the cold diabase walls.

Kainozoic Age of the Porphyry Dyke at Kettering.

The above evidence, I think, establishes the conclusion that the prophyry at Kettering is a dyke, intrusive into the diabase, and therefore younger than it. The age of the diabase sills in Tasmania has been demonstrated to be post Upper Jurassic, since in several places an intrusive contact with these sediments has been established. It is generally believed to be probably Cretaceous in age, and to have been intruded during the earth movements, which led to the breaking up of the Gondwanaland continental mass or masses.

If this view is correct the porphyry dyke at Kettering is probably post-Cretaceous in age, and in that case belongs to some part of the Kainozoic period.

Relations of the Kettering Dyke to the other Alkali Rocks of the District.

While the field evidence as described above defines the age of the Kettering dyke as post-Diabase, and therefore almost certainly Kainozoic, the field relations of the other alkali occurrences in the district only enable one to assert definitely that they are post-Lower Permo-Carboniferous.

We must turn to petrographic evidence to see whether or no there are sufficient petrographical and mineralogical resemblances between the various members of the suite of rocks to make it probable that they were all intruded during the same period.

For this purpose I have had a number of sections cut of rocks from the various localities mentioned above. This paper is not concerned with the detailed microscopic characters of the rocks, and my examination of the sections has simply been for the purpose of correlation of the various dyke occurrences.

Examination in the field or by hand specimens suggested that as far as naked eye examination goes the rocks which most closely resembled the Kettering dyke occur at Woodbridge and at Petchey's

Bay, the latter being the outcrop furthest to the S.W., the Kettering dyke the outcrop furthest to the N.E. in the area examined.

Microscopic Characters of the Alkali Porphyries.

A section kindly lent me by Mr. Twelvetrees, labelled Foyaite porphyry, Little Oyster Cove, contains as phenocrysts, dark-green pleochroic hornblende, pale-green augite in smaller prismatic crystals, plagioclase and small crystals of sphene. The ground-mass consists of small rectangular crystals of alkali felspar.

A section from the central part of the dyke at Kettering, Little Oyster Cove, shows that the rock has been considerably altered by weathering. The phenocrysts consist of Hornblende, more or less completely altered to aggregates of micaceous and chloritic material, altered plagioclase, with a ground-mass of small rectangular crystals of alkali felspar. Another section of the same rock at the contact with the diabase shows a definite, fine-grained selvage, consisting of a dense felspathic ground-mass, in which are set fairly fresh phenocrysts of plagioclase, and somewhat altered green hornblende. The hornblende in this rock is probably a soda hornblende, and the abundance of felspar, particularly of the alkali felspar of the ground-mass, shows that it is an alkali porphyry of intermediate composition. Somewhat noteworthy is the abundance of plagioclase phenocrysts.

With this rock may be compared those from Woodbridge and from Petchey's Bay. The Woodbridge rock in section shows as phenocrysts dark-green hornblende, pale-green alkali-augite, abundant plagioclase, and small sphenes set in a ground-mass of rectangular alkali felspars.

The Petchey's Bay porphyry in section has large phenocrysts of plagioclase, some of which may be anorthoclase, green aegirine-augite, and small sphenes in a ground-mass of rectangular alkali felspars.

There can be no doubt of the great general similarity of these three rocks. In each, the same ground-mass of alkali felspar is present, and the plagioclase phenocrysts predominate. Probably the Petchey's Bay rock, owing to the abundance of aegirine-augite is the most highly alkalic, the Woodbridge rock intermediate in alkali content, and the Kettering dyke somewhat less alkalic. Among the Port Cygnet rocks occur many whose texture and composition differs considerably from these three described above, but in the series near Port Cygnet various alkali porphyries are present

in such close field relations to the other types as to suggest strongly a genetic resemblance and reference to the same period of igneous activity.

One of the Port Cygnet porphyries in section shows as phenocrysts big crystals of orthoclase or sanidiare, green aegirine-augite, a little green hornblende, and small sphenes. In the ground-mass occur needles of pale augite, and the rest consists of lath-shaped and irregular alkali felspars, and probably some nepheline, and a very little plagioclase. This rock is distinctly more alkalic than the Kettering dyke or the Woodbridge and Petchey's Bay rocks, and yet in its texture and mineral content, allowing for greater alkali content, family resemblances are to be traced.

It would appear that all the rocks of the district are consanguineous and members of one petrographic province. But it is equally clear that differentiation was developed further in the Port Cygnet and Regatta Point areas than in the more outlying districts of Petchey's Bay in the S.W., and Woodbridge and Kettering in the N.E. This is evident from the fact that while some of the porphyries of the Port Cygnet area are in many respects allied to the Kettering, Woodbridge and Petchey's Bay rocks, there are also present in the central area, as Mr. Twelvetrees has described, adjoining and related rocks in which the mutually incompatible minerals, quartz and nepheline, are separately developed. This close association in the field of quartz-bearing augite syenites and related quartz-bearing rocks with others containing the felspathoids, nepheline and nosean or hauyn, provides an interesting example of what are probably nearly extreme types of differentiation in a magma of moderately alkalic character. The rocks of Kettering, Woodbridge and Petchey's Bay probably represent products intruded in a less differentiated form, and may quite possibly approximate in composition to the parent magma.

Comparison of the Alkali Rocks of S.E. Tasmania with other Australasian Types.

Hitherto the question of the age of these alkali rocks has been discussed, firstly, in the light of field evidence, particularly the evidence of the dyke at Kettering, and, secondly, on the evidence submitted that all the rocks of the area are consanguineous, and belong to one petrographic province, and, therefore, probably to one period of igneous activity. A third method of enquiry turns on the evidence of age and of character of the principal alkali

rocks of Australasia generally. Dr. Jensen,[1] among others, has discussed this problem. The age of some of the alkali rocks of Australasia is not yet susceptible of exact determination, since they only come into relation with and intrude rocks of high antiquity. Many were referred by Dr. Jensen to the Eocene period in New South Wales and Queensland, on somewhat slender evidence. The alkali rocks of New Zealand, described by Professor Marshall and others, are referred generally to the middle or upper part of the Kainozoic, and those of Victoria so far as known appear to belong to the period immediately preceding the newer basalts; that is, to the Mid-Kainozoic or the lower part of the Upper Kainozoic.

Some years ago, in a paper on the Volcanic Rocks of Victoria,[2] I tentatively included among Palaeozoic volcanic rocks certain alkali rocks in Eastern Victoria. This reference was based on Dr. Howitt's observations. Since then I have visited some of these districts in the field, and have been impressed by their recent looking characters, and now believe that they are probably of Middle to Upper Kainozoic age. The Mittagong-Bowral series of alkali rocks in New South Wales intrudes the Triassic sediments, and may well be Kainozoic in age. They are interesting in this connection, since they probably come nearest in chemical and mineralogical characters to the rocks of Port Cygnet, as they include syenites allied to bostonite, and aegirine-arfvedsonite-quartz-trachytes. The only alkali rocks in Australia definitely proved to be Palaeozoic in age are the series of alkaline eruptive rocks of the Cambewarra-Kiama districts, south of Sydney. These rocks consist mainly of lavas and tuffs, partly contemporaneous with the Upper Marine series of the Permo-Carboniferous, and partly with the Bulli coal measures. Their petrographic and chemical characters are, however, quite distinct from other alkali rocks in Australia, so far as known, and from the rocks of Port Cygnet, as they contain generally a good deal of potash, and are described as Orthoclase-basalts.

Apart from these Orthoclase-basalts of exceptional characters, it will be noted that other occurrences of alkali rocks intrude various members of the mesozoic, and may, therefore, be of Kainozoic age, while a considerable number are definitely known, not only to be of Kainozoic age, but to be not older than the Mid-Kainozoic. So far as analogy with other Australasian occurrences go it is in favour

1 Proc. Linn. Soc. N.S.W., 1908.

2 Aust. Assoc. Adv. of Sc., Brisbane, 1909. Pres. Add. to Sect. C.

of the view that the alkali rocks of the Port Cygnet and associated areas belong to the Kainozoic period. Objection may be raised that some of the Port Cygnet rocks are very decomposed, and a claim to greater age for them may be made on that account. While, however, some of the rocks are considerably altered so far as the surface outcrops are concerned, which alone are available for examination, fresh material from some of the rock types clearly related to the decomposed rocks can be obtained, and in any case arguments based on relative surface decomposition carry little weight when it is remembered that highly alkalic rocks are more susceptible generally of ready decomposition, and it is usually types richest in the alkalies which show the greatest change.

Conclusions.

The evidence presented in this paper warrants, in my belief, a revision of the previous view that the alkali rocks of the Port Cygnet district are of pre-diabase age, and probably belong to the top of the Permo-Carboniferous series, and it is here considered to be highly probable, if not definitely proved, that the alkali rocks are of Kainozoic age. The most powerful argument adduced is the field evidence of the intrusion of a dyke of alkali porphyry into the diabase (probably Cretaceous in age) at Little Oyster Cove, Kettering. Secondly, the close similarity of the Kettering rock with those of Woodbridge and Petchey's Bay is advanced, and the general similarity with some of the Port Cygnet rocks is pointed out. This leads to the second and more general conclusion, that between all the alkali rocks of the area consanguinity exists, arguing intrusion during a single period of igneous activity. A subsidiary argument, to reinforce the view of the Kainozoic age of the series, consists in a consideration of the age and nature of the alkali rocks of Australasia generally, wherein it is shown that such rocks as are fairly comparable in composition with the Port Cygnet series, and whose age is susceptible of anything approaching precise determination, have been shown to belong to the Kainozoic period. On these three grounds it is claimed that the alkali-porphyry of Kettering in particular and the alkali rocks of the district in general can be referred to the Kainozoic period with a high degree of probability.